LARGER FORAMINIFERA FROM THE LOWER EOCENE OF THE GEBEL GURNAH LUXOR, EGYPT

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ABSTRACT. Five species of *Nummulites* and four forms of *Operculina* are described and illustrated from the Lower Eocene Thebes Limestone Member of the Thebes Formation, Gebel Gurnah, Luxor, Egypt. *Operculina aegyptiaca*, *O. jiwani gebelensis*, and *O. libyca thebensis* are described as new.

THE Gebel Gurnah lies opposite Luxor on the western side of the Nile Valley at approximately latitude 25° 44′ North and longitude 32° 36′ East, and includes the well-known Valley of Kings. A hundred and twenty-five samples from the succession, which is about 450 m thick, have been thoroughly examined for planktonic and larger Foraminifera (Hamam 1971). The planktonic Foraminifera are in another paper, and the stratigraphic details are not repeated here; the relationships of the samples yielding larger Foraminifera are shown in Table 1; see also Said (1960).

STRATIGRAPHY AND PREVIOUS RECORDS

The lower shaley part of the Gebel Gurnah Section (sample Nos. 1–20) contains a rich and well-preserved planktonic foraminiferal fauna, but has not yielded any larger Foraminifera, nor does the lowermost part of the Thebes Limestone Member, Rock Unit III (sample Nos. 21–48) which is made of chalky limestone. However, in the overlying Rock Unit IV, which is mainly marly and dolomitic limestone, there are numerous and well-preserved larger Foraminifera. Of the twenty samples collected from this Unit IV, only seven (Nos. 57, 59, 62, 64, 65, 67, and 68) contain larger Foraminifera which are always associated with ostracods. Of the twenty-four samples collected from Rock Unit V, a white chalky and nodular limestone, only three (Nos. 84, 87, and 89) yielded larger Foraminifera, which are well preserved but occasionally coated with rock matrix. The uppermost part of the Thebes Limestone, Rock Unit VI, which includes relatively thinner beds of different limestones, contains, in general, an extremely poor fauna: none of the thirty-two samples collected from this unit yielded any matrix-free larger Foraminifera, but a few specimens were observed in thin section. Sample No. 93 contains many well-preserved ostracods, while sample No. 119 yielded poorly preserved and scarcely determinable planktonic Foraminifera.

Delanoue (1868) recorded four species of larger Foraminifera from the Gebel Gurnah section: *Nummulites distans* Deshayes var. *b* d'Archiac, *N. planulata* d'Orbigny, *N. guettardi* d'Archiac and Haime, *Operculina ammonea* Leymerie; while Cuvillier (1930) recorded: *N. atacicus* Leymerie, *N. globulus* Leymerie, *N. guettardi* d'Archiac and Haime, *O. libyca* Schwager, *O. ammonea* Leymerie. Said (1960, 1962)

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TABLE 1. Stratigraphical distribution of larger fossil Foraminifera in Gebel Gurnah Section, Luxor, Egypt.

Upper Palaeocene		Lower Eocene											
Gr. velascoensis Zone	Gr. aragonensis Zone	Gr. 'palmerae' Zone											Planktonic zonation
	I–III	IV							V			VI	Rock unit
	1–48	57	59	62	64	65	67	68	84	87	89	93–125	Sample numbers
					×	×	×	×					*Nummulites burdigalensis*
				×	×								*Nummulites globulus*
		×			×	×	×	×	×				*Nummulites silvanus*
						×							*Nummulites* aff. *solitarius*
									×	×	×		*Nummulites subramondi*
				×	×	×	×						*Operculina aegyptiaca*
										×	×		*Operculina jiwani gebelensis*
				×	×	×	×	×					*Operculina libyca libyca*
		×	×										*Operculina libyca thebensis*

recorded: *N. praecursor* (de la Harpe), *N. subramondi* de la Harpe, *O. libyca* Schwager, *Operculina* spp., also from the same section.

Nine larger fossil Foraminifera belonging to the genera *Nummulites* and *Operculina* have been identified in this study, both externally and in equatorial and axial section; 150 oriented thin sections were prepared. The relative proportions of the different species range from horizon to horizon: *O. libyca thebensis* dominates in sample No. 57; *N. globulus* and *O. aegyptiaca* dominate in sample No. 62; *N. burdigalensis* and *O. libyca* dominate in sample No. 64. The former species only is dominant in sample No. 65, while *N.* aff. *solitarius* also occurs rarely. *N. silvanus* commonly occurs in sample No. 68. All the above species have been found in Rock Unit IV. *O. jiwani gebelensis* subsp. nov. and *N. subramondi* are dominant in sample No. 89 of Rock Unit V. All nine taxa described in this paper are represented by megalospheric forms. Two of them, namely *N. burdigalensis* and *O. libyca*, are represented by both microspheric and megalospheric forms.

The species of *Nummulites* which occur in the Gebel Gurnah Section show strong similarity to the European forms, and three species of the five identified were originally described from Europe; *N. burdigalensis*, *N. globulus* and *N. silvanus*. The other two species, *N. subramondi* and *N.* aff. *solitarius*, are Egyptian forms. Among the important planktonic species found in Rock Unit III is *Globorotalia aragonensis* Nuttall, the highest appearance of which coincides with the top of this unit, which is therefore considered to represent Bolli's *Globorotalia aragonensis* Zone. Rock Units IV and V contain *Nummulites* and *Operculina* species of definite Lower Eocene age. From a study of synonyms in the literature, it is concluded that the ranges of the described species are as follows:

Nummulites burdigalensis	Lower Eocene–Eocene
Nummulites globulus	Lower Eocene–Middle Eocene
Nummulites silvanus	Upper Palaeocene–Lower Eocene
Nummulites aff. *solitarius*	Lower Eocene
Nummulites subramondi	Lower Eocene

Operculina aegyptiaca	upper Lower Eocene
Operculina jiwani gebelensis	middle–upper Lower Eocene
Operculina libyca	Lower Eocene
Operculina libyca thebensis	upper Lower Eocene

Rock Units IV and V, which overlie strata containing the *Globorotalia aragonensis* Zone faunas, and which themselves yield faunas with a Lower Eocene aspect, are considered to be upper Lower Eocene and are therefore correlated with Bolli's *Globorotalia palmerae* Zone of Trinidad. Rock Unit VI, which contains few planktonic or larger Foraminifera, is provisionally considered as the topmost part of the Lower Eocene in Egypt. The stratigraphical distribution of the *Nummulites* and *Operculina* species described in this paper are shown in Table 1.

SYSTEMATIC PALAEONTOLOGY

All the figured material is deposited in the British Museum (Natural History), London. The classification followed here is that proposed by Glaessner (1945) and modified by Pokorny (1958). The following terms are used to indicate relative size: less than 2·5 mm = small; 2·5 mm–5·0 mm = medium; above 5·0 mm = large.

Family NUMMULITIDAE de Blainville, 1825
Subfamily NUMMULITINAE de Blainville, 1825
Genus NUMMULITES Lamarck, 1801
Nummulites burdigalensis (de la Harpe)

Plate 28, figs. 1–8

1911 *Nummulites lucasanus* Defrance; Boussac, p. 52, pl. 2, figs. 41, 15.
1919 *Nummulites lucasi* d'Archiac; Douvillé (*pars*), p. 59, pl. 1, figs. 24–27, 37–38; non figs. 28–31.
1926 *Nummulina burdigalensis* de la Harpe, p. 71.
1929 *Nummulina lucasi* (d'Archiac); Rozlozsnik (*pars*), p. 113, pl. 2, figs. 4, 7; non p. 188, pl. 3, fig. 21.
1951 *Nummulites burdigalensis* (de la Harpe); Schaub, p. 113, pl. 1, figs. 13–17*b*; pl. 2, figs. 1–3, 5–8; pl. 3, figs. 1, 3–5; text-figs. 13, 74–81, 83–88*c*, 92*a*–95*c*.
1959 *Nummulites burdigalensis* (de la Harpe); Bieda, p. 21, pl. 1, figs. 1, 3, 4, 8.
1962 *Nummulites burdigalensis* (de la Harpe); Schaub, pp. 532, 534, text-figs. 1*a*, 2.
1967 *Nummulites burdigalensis* (de la Harpe); Nemkov, p. 168, pl. 19, figs. 4–16.

Description. Megalospheric form. External features. Test small, lenticular with raised polar region; equatorial periphery circular and occasionally partly serrate; axial periphery acute; 3–10 small pustules mainly in the polar region and also on the spiral filaments; diameter from 0·05 to 0·15 mm (average 0·12 mm); spiral filaments clearly visible, slightly curved, and radiate; from 19 to 28 in number, usually about 22. The diameter from 1·3 to 2·5 mm, thickness from 0·7 to 1·4 mm, and diameter/thickness ratio from 1·9/1 to 2·4/1.

Internal features. In axial section, protoconch circular from 0·10 to 0·15 mm in diameter; chamber cavity delta-shaped with straight lateral sides; alar prolongations distinct, well marked, relatively wide open, and becoming thinner towards the polar plugs; polar plugs conspicuous, striking, and flaring laterally towards the surface; plugs composed of a group of pillars mainly on the polar region and occasionally on the septal filaments; the base of the polar plug from 0·25 to 0·40 mm in diameter; lateral walls relatively thick, becoming slightly thinner in the last whorl, their thickness varying from 0·05 to 0·12 mm. In equatorial section the bilocular nucleoconch consists of circular to subcircular protoconch and smaller to subequal, hemicircular to reniform deuteroconch; the protoconch from 0·10 to 0·15 mm in diameter; the deuteroconch from 0·16 to 0·24 mm; the spire of three to five closely coiled, regular, and gradually opening whorls; the rate of opening varying from 1/1 to 1·3/1; spiral lamina of moderate thickness almost throughout the

spire; height of spiral cavity about 2·5 to 5 times the thickness of the spiral lamina; septa slightly curved in the early whorls, less curved in the later ones; 8–10 septa occur in the first whorl, 16–20 in the second, 17–21 in the third, and 21–24 in the fourth; chambers alar to rectangular in shape; chamber indices vary from 1/1 to 3/1.

Microspheric form. Internal features. Only one specimen (3·6 mm in diameter) found. In equatorial section, the initial chamber(s) indistinct; the slightly irregular spire is composed of about nine, gradually opening whorls.

No. of whorls	2	3	4	5	6	7	8	9
Opening rate	4·00	1·50	1·41	1·23	1·43	1·17	1·14	1·17

Spiral lamina moderate in thickness, which increases gradually from the initial part to the distal part; height of spiral cavity about 3·4–4·3 times thickness of spiral lamina; septa slightly curved to almost straight, slightly inclined on the spiral lamina, and sharply curved backward near the distal end; seven septa occur in the first whorl, 11 in the second, 17 in the third, 20 in the fourth; 21 in the fifth, 20 in the sixth, 25 in the seventh, 25 in the eighth, and 28 in the ninth; chambers rhomboid or rectangular in shape; chamber indices vary from 1/1 to 1·6/1.

Material. The megalospheric form of this species is common at some horizons of Rock Unit IV. Only one specimen of the microspheric form was found.

Remarks. The megalospheric form of *N. burdigalensis* is distinguished in the present material from associated species in having a larger test; raised polar region; acute axial periphery; circular and occasionally partly serrate equatorial periphery; in the occurrence of pustules and granulations; in having relatively large bilocular nucleoconch; delta-shaped chamber cavities with straight lateral sides and well-marked alar prolongations, conspicuous polar plugs; regularly coiled spire and almost straight, slightly curved septa. It is mainly distinguished from *N. globulus* Leymerie in having surface pustules and granulations, serrate equatorial periphery, thinner lateral laminae, delta-shaped chamber cavities with straight lateral sides, and thinner spiral lamina.

Distribution. A type locality for *N. burdigalensis* was not designated, the present species only mentioned as occurring in the Eocene of France, Italy, U.S.S.R., and Switzerland. Later, it was described from the Lower Eocene (Lower–Upper Ypresian) of Switzerland by Schaub (1951), from the Eocene of Poland by Bieda (1959), and from the Eocene of the Soviet Union by Nemkov (1967). In the Gebel Gurnah Section, *N. burdigalensis* occurs in the upper Lower Eocene.

EXPLANATION OF PLATE 28

Figs. 1–8. *Nummulites burdigalensis* (de la Harpe). 1 (P 49793), 2 (P 49794), equatorial sections of megalospheric specimens, ×24. 3 (P 49795), 4 (49796), external views of megalospheric specimens, ×19. 5 (P 49797, 6 (P 49798), axial sections of megalospheric specimens, ×24. 7 (P 49799), equatorial section of microspheric specimen, ×12. 8, part of the equatorial section of fig. 7 enlarged, ×24. 1, 2, 7, 8 from sample 64; 3, 4, 5, 6 from sample 65, Rock Unit IV, Thebes Limestone Member.

Figs. 9–14. *Nummulites subramondi* de la Harpe. 9 (P 49818), 10 (P 49819), equatorial sections of megalospheric specimens, ×24. 11 (P 49820), 12 (P 49821), axial sections of megalospheric specimens, ×24. 13 (P 49822), 14 (P 49823), external views of megalospheric specimens, fig. 13 × 16, fig. 14 × 19. 9–14 from sample 89, Rock Unit V, Thebes Limestone Member.


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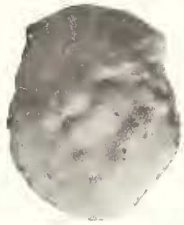
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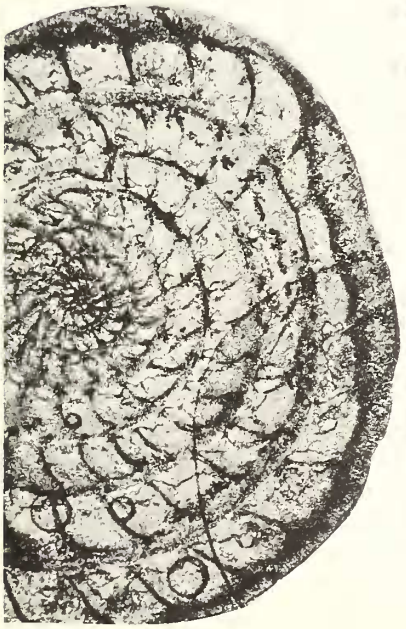
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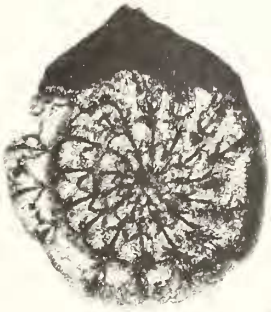
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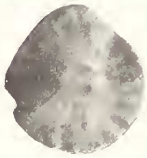

14

HAMAM, Eocene Foraminifera from Egypt

Nummulites globulus Leymerie

Plate 29, figs. 1–7

1846 *Nummulites globulus* Leymerie; p. 359, pl. 13, fig. 14*a–d*.
1919 *Nummulites globulus* Leymerie; Douvillé, p. 54, pl. 1, figs. 12–17.
1926 *Nummulites globulus* d'Archiac; Doncieux, p. 37, pl. 5, figs. 1–7.
1926 *Nummulites globulus* Leymerie; Nuttall, p. 116.
1927 *Nummulites globulus* Leymerie var. *indicus* Davies, p. 271, pl. 10, figs. 6–10.
1929 *Nummulites globulus* Leymerie; Gomez Llueca, p. 105, pl. 5, figs. 6–10.
1930 *Nummulites globulus* Leymerie; Cuvillier (*pars*), p. 72, non p. 140.
1931 *Nummulites globulus* Leymerie; de Cizancourt, p. 209, pl. 22, fig. 5.
1937 *Nummulites globulus* Leymerie; Davies and Pinfold, p. 22, pl. 3, fig. 3.
1938 *Nummulites globulus* Leymerie; Flandrin, p. 39, pl. 3, figs. 21–23.
1951 *Nummulites globulus* Leymerie; Schaub, p. 103, pl. 1, fig. 1; text-figs. 42*a*–49*b*, 51*a*, *b*.
1952 *Nummulites globula* Leymerie; Azzaroli, p. 120, pl. 9, figs. 4, 5.
1954 *Nummulites globulus* Leymerie; Smout, p. 79, pl. 15, figs. 5, 6.
1959 *Nummulites globulus* Leymerie; Papp, p. 167, text-figs. 3 (4, 5*a*, *b*).
1967 *Nummulites globulus* Leymerie; Nemkov, p. 202, pl. 26, figs. 1–8.

Description. Megalospheric form. External features. Test small to medium-sized, lenticular to subglobular; equatorial periphery circular; axial periphery subacute to acute in well-preserved specimens; polar boss or postules not seen; septal filaments numerous, weakly curved, regular, radiate, and flush; occasionally weakly raised; surface rather smooth. The diameter varies from 1·0 to 2·8 mm, thickness from 0·6 to 1·6 mm, and diameter/thickness ratio from 1·4/1 to 1·7/1.

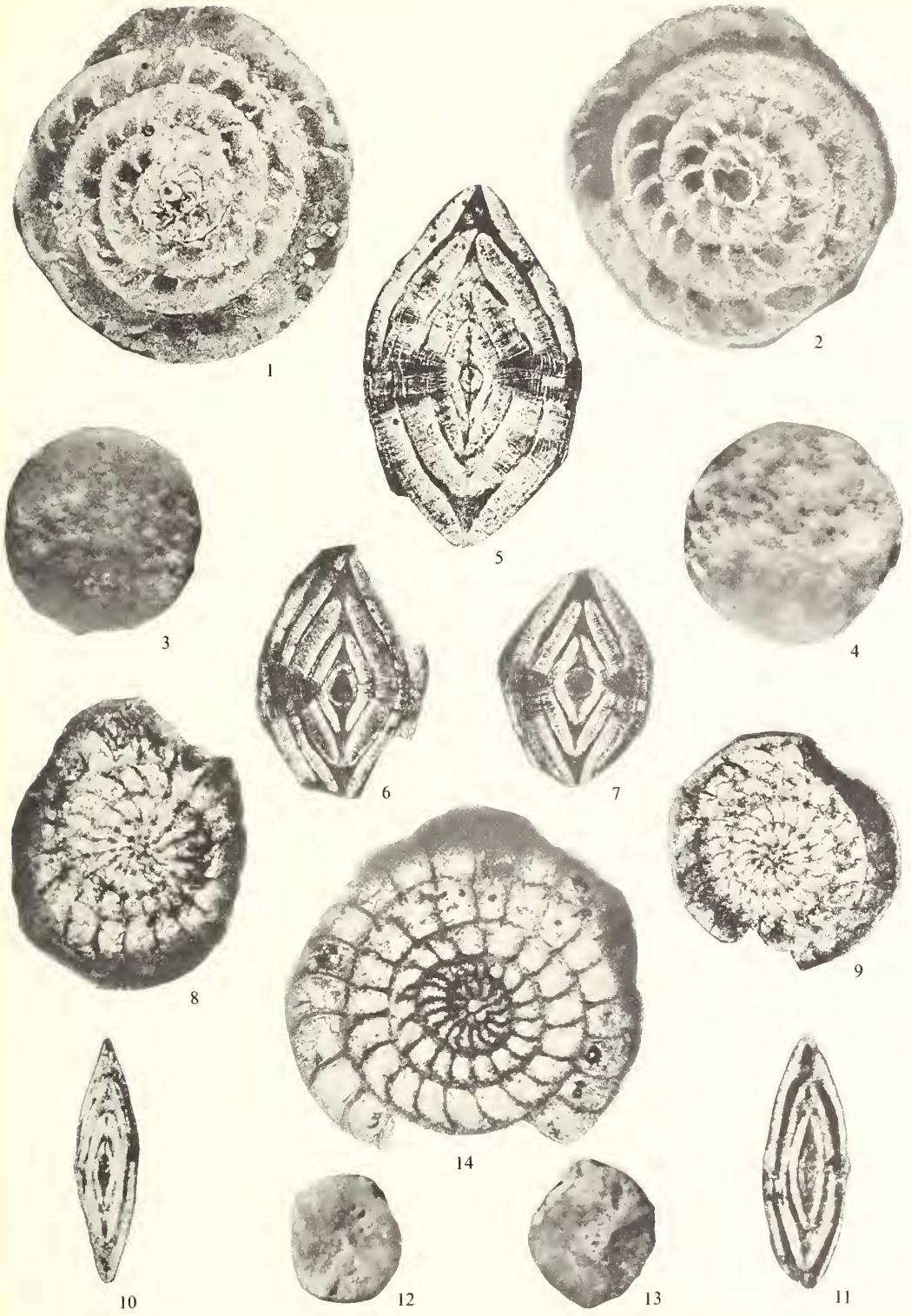
Internal Features. In axial section, protoconch circular and varies from 0·12 to 0·17 mm in diameter; chamber cavity narrow, wedge- to delta-shaped, sometimes with slightly concave lateral sides; alar prolongation distinct, well marked, wide open, and becoming thinner towards the conspicuous polar plugs, which flare towards the surface, where they vary from 0·25 to 0·5 mm diameter; these plugs are not visible externally because they are concealed by the overlapping of the lateral laminae of the last whorls; lateral walls layered, thick, and maintaining their thickness from the polar region to the equatorial periphery, its thickness varies from 0·07 to 0·17 mm; marginal cord most often indistinct. In equatorial section, bilocular nucleoconch comprises a circular protoconch and reniform deuteroconch; the protoconch varies from 0·10 to 0·20 mm, the average is about 0·17 mm; the deuteroconch from 0·07 × 0·15 to 0·10 × 0·17 mm, the average is about 0·10 × 0·15 mm; the maximum height of nucleoconch varies from 0·20 to 0·25 mm with a spire of three to four closely coiled, usually regular, and gradually opening whorls; the rate of spire opening varies from 1/1 to 2·1/1, the average is 1·1/1 to 1·5/1; spiral lamina relatively thick, thickness varying; height of spiral cavity about one to five times thickness of spiral lamina (average is three times); septa slightly curved in the early whorls, less so in the later ones, relatively thick with marked curvature near distal end; about 8–10 septa occur in the first whorl, 13–18 in the second, 19–24 in the third, and about 21 in the fourth, chambers alar to rectangular in shape; chamber indices vary from 1/1 to 2/1, the average is 1/1 to 1·5/1.

EXPLANATION OF PLATE 29

Figs. 1–7. *Nummulites globulus* Leymerie. 1 (P 49802), 2 (P 49803), equatorial sections of megalospheric specimens, × 24. 3 (P 49804), 4 (P 49805), external views of metalospheric specimens, × 19. 5–7 (P 49806–49808), axial sections of megalospheric specimens, × 24. Sample 62, Rock Unit IV, Thebes Limestone Member.

Figs. 8–13. *Nummulites silvanus* Schaub. 8 (P 49811), 9 (P 49812), equatorial sections of megalospheric specimens, × 24. 10 (P 49813), 11 (P 49814), axial sections of megalospheric specimens, × 24. 12 (P 49815), 13 (P 49816), external views of megalospheric specimens, × 16. Sample 68, Rock Unit IV, Thebes Limestone Member.

Fig. 14. *Nummulites* aff. *solitarius* de la Harpe. P 49817, equatorial section of megalospheric specimen, × 24. Sample 65, Rock Unit IV, Thebes Limestone Member.



HAMAM, Eocene Foraminifera from Egypt

Material. No microspheric form found. Megalospheric forms are abundant at some horizons in Rock Unit IV.

Remarks. N. globulus is distinguished from other *Nummulites* in having a larger and subglobular test; a rather smooth surface; thick lateral laminae; wedge-shaped chamber cavities; well-marked alar prolongations; distinct and well-developed polar plugs; large nucleoconch with larger and circular protoconch and smaller and reniform deuteroconch; closely coiled spire; thick spiral lamina and almost straight, slightly curved septa. Schaub (1951) described *N. pernotus* from the Palaeocene to Lower Eocene of Switzerland, a form very close to the present species. Earlier, Davies (1927) described both *N. globulus* var. *indicus* and *N. wadiai* from the Ranikot Beds of Thal in Pakistan. Bayliss (1961, unpublished thesis) treated Davies's variety as synonymous with the typical species, a view shared by the present author. In the Gebel Gurnah Section, some individuals in the population of the present species show strong affinities to *N. wadiai* Davies, and further study may prove these species conspecific.

Distribution. Leymerie described *N. globulus* from the Tertiary of France. It was also described from the Lower Eocene of the Pyrénées, France, by Douvillé (1919); from the Middle Eocene of Spain by Gomez Llueca (1929); from the Lower to Middle Eocene of Albania by Cizancourt (1931); from the Lower to Middle Eocene of Algeria by Flandrin (1938); from the Palaeocene to Lower Eocene of Switzerland by Schaub (1951); from the Middle Eocene of Somaliland by Azzaroli (1952); from the Lower Eocene of Qatar by Smout (1954); from the Lower Eocene of Austria by Papp (1959); from Lower to Middle Eocene in the Rakhi Nala Section of Pakistan by Bayliss (1961), and from the Eocene of the Soviet Union by Nemkov (1967). In the Gebel Gurnah Section, *N. globulus* occurs in the upper Lower Eocene.

Nummulites silvanus Schaub

Plate 29, figs. 8–13

1951 *Nummulites silvanus* Schaub, p. 153, text-figs. 189*a*–194*c*.

Description. Megalospheric form. External features. Test small, laterally compressed and flatly lenticular usually without any markedly developed structures in the polar region such as pustules, granules, or bosses; equatorial periphery circular to subcircular; axial periphery acute to subacute; spiral filaments occasionally well visible, thin, slightly curved, and rarely ramified. The diameter varies from 1·1 to 2 mm, thickness varies from 0·3 to 0·8 mm, and diameter/thickness ratio from 2·2/1 to 3·7/1.

Internal features. In axial section the chamber cavity appears as a high, narrow triangle, with straight lateral sides and distinct alar prolongations; polar plugs indistinct or absent; lateral walls thin, delicate, and maintaining their thickness throughout; marginal cord indistinct. In equatorial section, the bilocular nucleoconch is composed of a subcircular to ovoid protoconch and a smaller or subequal, ovoid deuteroconch with straight separating wall; the protoconch varies from 0·05 to 0·10 mm in diameter; the deuteroconch from 0·04 × 0·07 to 0·05 × 0·10 mm; the maximum height of nucleoconch varies from 0·11 to 0·15 mm; the spire is composed of 2·5 to 4 regular to irregular, narrow, and gradually opening whorls; the rate of spire opening varies from 1/1 to 1·6/1; spiral lamina thin and almost regular; height of spiral cavity about four to six times thickness of spiral lamina; septa thin, simply curved to irregular in shape, occasionally the distal part of some gently curving septa suddenly bends forwards to join the spiral lamina; about 9–11 septa occur in the first whorl, 16–20 in the second, 18–22 in the third, and 22–24 in the fourth; chambers variable in shape, rectangular, crescentic, or nearly rhomboid; chamber indices vary from 1/1 to 3·3/1.

Material. Megalospheric forms are rare to common in Rock Unit IV. No microspheric forms found.

Remarks. Nummulites silvanus is distinguished from other *Nummulites* in having a laterally compressed, flatly lenticular test; thin, slightly curved, and rarely ramified spiral filaments; high chamber cavities; thin and delicate lateral walls; straight separating wall between protoconch and deuteroconch; thin spiral lamina; simply curved to irregular septa which sometimes bend forwards to join spiral lamina and rectangular, crescentic, or nearly rhomboid chambers. It lacks pustules, granules, or polar bosses and polar plugs. It is similar to *N. praecursor* (de la Harpe) (= *N. biarritzensis* d'Archaic var. *praecursor* de la Harpe) but has a narrower spire, a smaller nucleoconch, a thinner spiral lamina, and a more compressed test.

Distribution. The present species was originally described from the Upper Palaeocene and from Upper Palaeocene–Lower Eocene transition beds of the Schlierenflysch, Switzerland, by Schaub (1951). In the Gebel Gurnah Section, *N. silvanus* occurs in the upper part of the Lower Eocene.

Nummulites aff. *solitarius* de la Harpe

Plate 29, fig. 14

Description. Megalospheric form. Internal features. Only two specimens found, 1·67 mm and 2·25 mm in diameter. The bilocular nucleoconch comprises a circular protoconch and subequal, subcircular deuteroconch; the protoconch varies from 0·05 to 0·06 mm in diameter; the deuteroconch varies from 0·02 × 0·04 to 0·05 × 0·05 mm; the maximum height of nucleoconch varies from 0·10 to 0·12 mm; the spire is composed of four to five moderately coiled, regular to slightly irregular whorls; three whorls to a radius of 0·7–0·8 mm; the rate of spire opening varies from 1·1/1 to 1·6/1; spiral lamina relatively thin; height of spiral cavity about 3 to 6·5 times thickness of spiral lamina; septa irregular in general, small, closely arranged, and curved in the earlier whorls, becoming larger, irregular, and almost straight or more curved; 12 septa occur in the first whorl, 17–19 in the second, 17–19 in the third, 20–22 in the fourth, and 23 in the fifth; chambers rhomboid or crescentic to rectangular; chamber indices vary from 1·5/1 to 5·5/1.

Material. Two specimens only.

Remarks. Nummulites solitarius de la Harpe was originally described from 'Libysche Stufe' of El-Guss-Abu-Said, Farafrah Oasis, Egypt. Later, Schaub (1951) studied the topotypes and also material from Switzerland, and considered its range to be Paleocene–Lower Eocene. Gebel Gurnah specimens slightly differ from the typical in having a slightly lower rate of spire opening and slightly longer earlier sutures.

Distribution. In the Gebel Gurnah Section, *N.* aff. *N. solitarius* occurs in the upper Lower Eocene.

Nummulites subramondi de la Harpe

Plate 28, figs. 9–14

1883 *Nummulites ramondi* Defrance; de la Harpe, p. 173, pl. 31 (2), figs. 5–12*a* (as figs.).
1883 *Nummulites subramondi* de la Harpe, p. 175, pl. 31 (2), figs. 13–17 (10 figs.).
1951 *Nummulites subramondi* de la Harpe; Schaub, p. 128, text-figs. 119–127*c*.
1959 *Nummulites subramondi* de la Harpe; Papp, p. 167, text-figs. 4 (1*a*, *b*).
1967 *Nummulites subramondi* de la Harpe; Nemkov, p. 249, pl. 38, figs. 1–3.

Description. Megalospheric form. External features. Test small, lenticular with conspicuous strongly raised polar boss which may be flat- or convex-topped, the diameter of which varies from 0·15 to 0·30 mm and

height from 0·05 to 0·12 mm, mean 0·07 to 0·12 mm; equatorial periphery circular to subcircular; axial periphery acute; spiral filaments present, radiate and almost straight, from 17 to 24 in number (average about 20). The diameter varies from 0·75 to 1·65 mm, thickness from 0·37 to 1·00 mm, and diameter/thickness ratio from 1·5/1 to 3/1.

Internal features. In axial section, protoconch circular from 0·05 to 0·07 mm in diameter; chamber cavity appears as a narrow isosceles triangle with straight lateral sides and distinct alar prolongations which maintain their width to the conspicuous polar plugs, striking and flaring laterally from near the nucleoconch towards the surface and protruding externally to constitute well-developed and strongly raised polar bosses; the bases of plugs have the same diameter as the bosses; lateral walls layered, of moderate (0·04–0·10 mm) thickness throughout; those of the last whorl are slightly thinner; marginal cord occasionally distinct in the last whorl. In equatorial section, bilocular nucleoconch comprises a circular to subcircular protoconch and a smaller or subequal, ovoid deuteroconch; the protoconch varies from 0·05 to 0·07 mm in diameter; the deuteroconch varies from 0·02 × 0·06 to 0·05 × 0·06 mm; the diameter of nucleoconch varies from 0·08 to 0·12 mm; the spire is composed of three to four regular and gradually opening whorls; first whorl hardly open, followed by moderately open ones; the rate of opening varies from 1/1 to 1·6/1; spiral lamina rather thin and more or less regular; height of spiral cavity about four times thickness of spiral lamina; septa mostly straight, thickened, and very weakly inclined to the spiral lamina; about 8–9 septa occur in the first whorl, 14–15 in the second, 16–19 in the third, and about 22 in the fourth; chambers similar in outline, subquadrate or rectangular; chamber indices vary from 1·1/1 to 2/1.

Material. The megalospheric form is common at some horizons in Rock Unit V. No microspheric form found.

Remarks. Nummulites subramondi is distinguished from associated species in having conspicuous and strongly raised polar bosses; even equatorial periphery; almost straight septal filaments; narrow isosceles triangular chamber cavity in axial section, well-marked, open alar prolongations which maintain their width throughout; rather thin spiral lamina; straight, thickened, and iron-oxidized septa which are almost upright situated on spiral lamina and isometric, subquadrate, or rectangular chambers. Although Gebel Gurnah specimens show slight differences from the type material described by de la Harpe (1883) and Schaub (1951) from the Lower Eocene of Egypt, they are considered to be conspecific. They show all the important diagnostic characters of this species.

Distribution. De la Harpe described *N. subramondi* from the Lower Eocene of Gebel Ter, Nile Valley, Egypt. Later, it was described from the Lower Eocene of Switzerland by Schaub (1951), from the Lower Eocene of Austria by Papp (1959), and from the Lower Eocene of the Soviet Union by Nemkov (1967). In the Gebel Gurnah Section, *N. subramondi* occurs in the upper Lower Eocene.

EXPLANATION OF PLATE 30

Figs. 1–8. *Operculina libyca* Schwager. 1 (P 49842), 2 (P 49843), equatorial sections of megalospheric specimens, fig. 1 × 19, fig. 2 × 10. 3 (P 49844), 4 (P 49845), axial sections of megalospheric specimens, fig. 3 × 24, fig. 4 × 19. 5 (P 49846), external view of megalospheric specimen, × 19. 6 (P 49848), external view of microspheric specimen, × 19. 7 (P 49849), equatorial section of microspheric specimen, × 9·3. 8, part of the equatorial section of fig. 7 enlarged, × 24. 1, 2, 7, 8 from sample 64; 3–6 from sample 65, Rock Unit IV, Thebes Limestone Member.

Figs. 9–14. *Operculina jiwani gebelensis* subsp. nov. 9 (P 49834), 10 (P 49835), equatorial sections of megalospheric paratypes, × 24. 11 (P 49836), external view of megalospheric paratype, × 19. 12 (P 49837), external view of holotype (megalospheric form), × 19. 13 (P 49838), 14 (P 49839), axial sections of megalospheric paratypes, × 24. Sample 89, Rock Unit V, Thebes Limestone Member.

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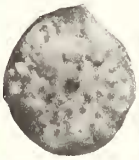

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HAMAM, Eocene Foraminifera from Egypt

Genus OPERCULINA d'Orbigny, 1826
Operculina aegyptiaca sp. nov.

Plate 31, figs. 1–6

Diagnosis. An *Operculina* with small to medium-sized test, a subcircular equatorial periphery, radiate and slightly raised surface ridges running along the sutures, rather wide and isosceles triangular chamber cavities with perfectly straight sides, and curved to slightly irregular and thickened septa.

Description. Megalospheric form. External features. Test small to medium sized, strongly bilaterally compressed; equatorial periphery subcircular; axial periphery acute; surface ornamented with narrow, slightly raised ridge-like structures running along the sutures; intercameral sutures distinct, weakly curved, radial; from 21 to 26 in the last whorl; spiral suture distinct and slightly depressed. The diameter varies from 1·75 to 3·55 mm, thickness from 0·25 to 0·45 mm, and diameter/thickness ratio from 7/1 to 8/1.

Internal features. In axial section, the protoconch varies from 0·05 to 0·10 mm in diameter; chamber cavity rather wide, open, long isosceles triangular in shape with perfectly straight lateral sides, gradually attenuated in thickness towards the equatorial periphery and with inwards convex base; lateral wall rather thick, layered, and varies from 0·10 to 0·125 mm in thickness near the nucleoconch, becoming much thinner in the last whorl where it varies from 0·0375 to 0·075 mm. In equatorial section, bilocular, fairly large nucleoconch comprising a circular to subcircular protoconch and subequal reniform deuteroconch; separating wall slightly convex outwards; the protoconch varies from 0·05 to 0·125 mm in diameter; the deuteroconch from $0{\cdot}0625 \times 0{\cdot}0875$ to $0{\cdot}10 \times 0{\cdot}125$ mm; the maximum diameter of nucleoconch from 0·20 to 0·22 mm; the spire has two to three regular to slightly irregular and rapidly opening whorls; the rate of spire opening varies from 1·4/1 to 2/1; spiral lamina rather thin, regular, and increasing in thickness distally; height of spiral cavity about 2 to 6·25 times thickness of spiral lamina; septa long, thickened, slightly to moderately curved, occasionally irregular, almost regularly spaced, and maintaining their thickness throughout; at the distal end they are sharply curved backwards to join the spiral lamina; about 8–9 septa occur in the first whorl, 16–18 in the second, and 22–26 in the third; chambers higher than long and alar to crescentic in shape; chamber indices vary from 1·5/1 to 3·25/1.

Material. The microspheric form has not been found. Megalospheric forms are common in some horizons of Rock Unit IV.

Remarks. Operculina aegyptiaca sp. nov. is distinguished from *O. gigantea* Mayer and *O. ammonea* Leymerie, mainly in being much smaller, in having a subcircular equatorial periphery, slightly raised ridges running over weakly curved sutures, rather wide triangular chamber cavities with perfectly straight sides in axial section, curved and slightly irregular and thickened septa, and alar to crescentic chambers. *O. alpina* Douvillé, from the Eocene of France, has a larger test, a higher rate of spire opening, and almost straight septa. *O. libyca* Schwager mainly differs in having a complanate to roughly polygonal test; granulated surface; narrower, higher, weakly attenuated, and almost parallel-sided chamber cavities in axial section; thinner septa and spiral lamina; a lax spire and crescentic to rectangular chambers in equatorial section. *O. libyca thebensis* subsp. nov. differs in having rather smooth complanate and much thinner test with raised polar knob; very thin chamber cavities with slightly convex sides inwards in axial section; much thinner septa and spiral lamina; almost straight and regularly spaced septa which give rise to almost rectangular chambers; a lax spire in equatorial section.

Distribution. In the Gebel Gurnah Section, *O. aegyptiaca* sp. nov. occurs in the upper Lower Eocene.

Operculina jiwani Davies *gebelensis* subsp. nov.

Plate 30, figs. 9–14

Diagnosis. An *Operculina* with a small test, slightly raised polar region, subcircular equatorial periphery, granulated and/or raised intercameral sutures, strongly depressed and groove-like spiral suture, conspicuous polar pustule, very thin and high chamber cavity in axial section, thick lateral wall, thin last whorl, very small nucleoconch, and rather thick and slightly curved septa in equatorial section.

Description. Megalospheric form. External features. Test small, bilaterally compressed, and with slightly raised polar region; equatorial periphery subcircular to ovoid with high apertural faces; axial periphery acute; surface coarsely ornamented with pustules and granules which are situated on sutures; granules from 24 to 41 in number and from 0·025 to 0·10 mm in diameter; they increase in number in the later whorls and usually fuse in ridge-like structures along the sutures; in the polar region there is a single conspicuous polar pustule, varying from 0·075 to 0·175 mm in diameter; intercameral sutures almost straight, slightly curved, radial, and granulated or covered with ridges; 20 to 26 sutures in the last whorl; spiral sutures depressed and groove-like as a result of coarse surface ornamentation. The diameter varies from 1·20 to 2·20 mm, thickness from 0·20 to 0·55 mm, and diameter/thickness ratio from 3·4/1 to 6/1.

Internal features. In axial section, protoconch circular and varies from 0·025 to 0·0625 mm in diameter; chamber cavity very narrow, high, and its base convex inwards; polar pustule conspicuous, about 0·15 mm in diameter; polar pustule and surface granules do not express any internal features such as internal pillars and are thickenings of lateral walls; lateral wall thick (about 0·15 mm in the middle of the test), becoming straight, very thin, and delicate in the last whorl where it does not exceed 0·025 mm in thickness. In equatorial section, the very small bilocular nucleoconch is composed of circular protoconch and smaller reniform deuteroconch; the protoconch from 0·025 to 0·06 mm in diameter; the deuteroconch from $0{\cdot}02 \times 0{\cdot}022$ to $0{\cdot}032 \times 0{\cdot}05$ mm; the maximum height of nucleoconch from 0·062 to 0·09 mm; the spire has 3 to $3\frac{1}{2}$, regularly and rapidly opening whorls; the rate of spire opening varies from 1·3/1 to 1·8/1, spiral lamina rather thin increasing in thickness distally; height of spiral cavity about five to eight times thickness of spiral lamina; septa slightly to moderately curved, rather thick, regularly spaced and at their distal end curved backwards to join the spiral lamina; 8–10 septa occur in the first whorl, 14–15 in the second, and 18–21 in the third; chambers higher than long, alar or crescentic in shape; chamber indices vary from 2/1 to 2·7/1.

Material. The microspheric form has not been found. The megalospheric form is common in some horizons of Rock Unit V.

Remarks. This subspecies differs from *Operculina jiwani* Davies s.s. mainly in having smaller test, more lax spire, thinner last whorl, and the presence of a conspicuous single polar pustule. *O. semiivoluta* Nemkov and Barkhatova is similar but differs in being slightly involute, in having a roughly polygonal outline to the equatorial periphery, a ridged rather than a granulated surface, and more septa per whorl.

Distribution. In the Gebel Gurnah Section, *O. jiwani gebelensis* occurs in the upper Lower Eocene; the subspecies also occurs in the Lower Eocene Ghazij Formation of Pakistan (Bayliss 1961, unpublished Ph.D. thesis).

Operculina libyca libyca Schwager

Plate 30, figs. 1–8; Plate 31, fig. 7

1883 *Operculina libyca* Schwager, p. 142, pl. 29 (6), fig. 2*a–b*.
1930 *Operculina libyca* Schwager; Cuvillier, p. 71.
1953 *Operculina libyca* Schwager; Le Roy, p. 42, pl. 11, figs. 14, 15.

Description. Megalospheric form. External features. Test small to medium in size, thin, strongly bilaterally compressed, and coarsely roughened at the middle; equatorial periphery complanate to roughly polygonal;

axial periphery acute; coarsely ornamented with granulations at the middle and along the sutures of early whorls; granules variable, sometimes subequal in size, becoming much smaller and fused together, constituting low ridge-like structures on later sutures; granules from 28 to 60 in number and from 0·025 to 0·125 mm in diameter; intercameral sutures indistinct in the early part, becoming distinct, granulated, or covered with low ridge-like structures, almost straight, radiate, and raised later; from 19 to 26 in the last whorl; spiral suture indistinct proximally, becoming distinct, slightly depressed later. The diameter from 1·65 to 3·2 mm, thickness from 0·40 to 0·45 mm, and diameter/thickness ratio from 4·1/1 to 7·1/1.

Internal features. In axial section, protoconch circular and varies from 0·05 to 0·10 mm in diameter; chamber cavity narrow, high, weakly attenuated in thickness towards the equatorial periphery, giving a parallel-sided impression, and with its base slightly convex inwards; the last whorl shows marked decrease in thickness from 0·15 to 0·225 mm, surface granules appear merely as thickenings of lateral walls, which are rather thick (0·125 to 0·175 mm) near the nucleoconch, becoming thinner in the last whorl (0·05 to 0·10 mm). In equatorial section, large bilocular nucleoconch of circular to subcircular protoconch and subequal to slightly larger reniform deuteroconch; separating wall either straight or convex outwards; the protoconch from 0·075 to 0·12 mm in diameter; the deuteroconch from 0·05 × 0·075 to 0·10 × 0·137 mm, the maximum height of nucleoconch from 0·15 to 0·22 mm; the spire of $2\frac{1}{2}$ to $3\frac{3}{4}$ regular and rapidly opening whorls; the distal part of last whorl is sometimes narrower than the proximal part and wavy, giving the roughly polygonal outline of the equatorial periphery; the rate of spire opening from 1·6/1 to 2·5/1; spiral lamina thin, regular, increasing in thickness distally; height of spiral cavity about 4 to 12·5 times thickness of spiral lamina; septa long, almost straight, very weakly curved, of even thickness, and regularly spaced; distally they sharply curve backwards to join the spiral lamina; very few septa do not reach the spiral lamina and curve backwards to meet previous ones; about 9–11 septa occur in the first whorl, 15–19 in the second, and 23–26 in the third; chambers higher than long and almost rectangular to crescentic in shape; chamber indices vary from 1·75/1 to 3·8/1.

Microspheric form. External features. Test similar to that of megalospheric form in shape and surface ornamentation; however, those of the microspheric form are larger with their diameter reaching 5·0 mm.

Internal features. Two specimens of the microspheric form were studied in equatorial section. The spire of 5 to $5\frac{1}{2}$ regular and rapidly opening whorls; the rate of spire opening slightly less than megalospheric form, from 1·75/1 to 1·9/1; spiral lamina rather thin, regular, and increasing in thickness distally; height of spiral cavity about four to nine times thickness of spiral lamina; septa long almost straight, very weakly curved, maintaining their thickness throughout, and regularly spaced; at distal end they sharply curve backwards to join the spiral lamina; a few septa only do not reach spiral lamina and curve backwards to meet previous ones; about 9 septa in the first whorl, 13 in the second, 17–21 in the third, 24–26 in the fourth, and 31–36 in the fifth; chamber indices vary from 2/1 to 5·5/1.

Material. The megalospheric form is abundant at some horizons of Rock Unit IV, while microspheric forms are rare.

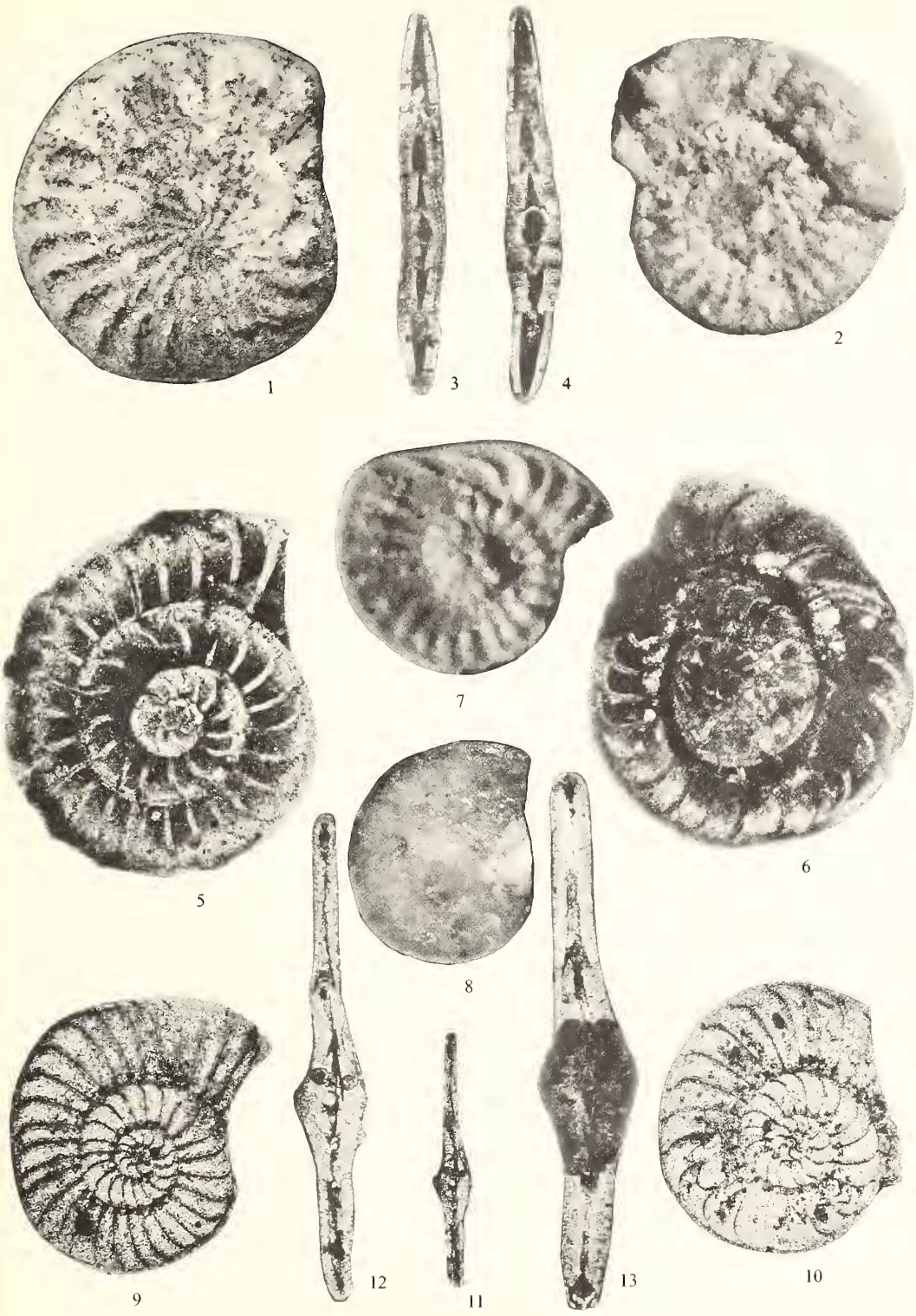
Remarks. Operculina libyca libyca mainly differs from *O. aegyptiaca* sp. nov. in having a granulated surface, a higher rate of spire opening, higher chambers and thinner spiral lamina and septa. It also differs from *O. libyca thebensis* in having a larger and granulated test; slightly fewer chambers; a relatively thicker lateral wall, spiral

EXPLANATION OF PLATE 31

Figs. 1–6. *Operculina aegyptiaca* sp. nov. 1 (P 49824), external view of holotype (megalospheric form), × 19. 2 (P 49825), external view of megalospheric paratype, × 19. 3 (P 49826), 4 (P 49827), axial sections of megalospheric paratypes, × 24. 5 (P 49828), 6 (P 49829), equatorial sections of megalospheric paratypes, fig. 5 × 24, fig. 6 × 19. Sample 62, Rock Unit IV, Thebes Limestone Member.

Fig. 7. *Operculina libyca* Schwager. 7 (P 49847), external view of megalospheric specimen, × 19. Sample 65, Rock Unit IV, Thebes Limestone Member.

Figs. 8–13. *Operculina libyca thebensis* subsp. nov. 8 (P 49852), external view of holotype (megalospheric form), × 28. 9 (P 49853), 10 (P 49854), equatorial sections of megalospheric paratypes, × 24. 11, 12 (P 49855), axial section of megalospheric paratype, fig. 11 × 24, fig. 12 × 48. 13 (P 49856), axial section of megalospheric paratype, × 48. Sample 57, Rock Unit IV, Thebes Limestone Member.



HAMAM, Eocene Foraminifera from Egypt

lamina, and septa; a larger protoconch, deuteroconch, and nucleoconch, and in lacking the inflated polar region. The form described by Le Roy (1953) from the Maqfi Section shows fewer whorls, otherwise it agrees well with Schwager's species. Nemkov (1967, p. 271) recorded *O. libyca* from the south of the Soviet Union, but provided no illustrations, which makes comment difficult.

Distribution. O. libyca was originally described from Eocene Libysche Stufe of El-Guss-Abu-Said, Farafra Oasis, and from Remihma, Egypt. Cuvillier (1930) recorded it from many Lower Eocene sections in Egypt. Le Roy (1953) described it from the Lower Eocene of Maqfi Section, Farafra Oasis, Egypt. In the Gebel Gurnah Section, *O. libyca libyca* occurs in the upper Lower Eocene.

Operculina libyca thebensis subsp. nov.

Plate 31, figs. 8–13

Diagnosis. An *Operculina* with a thin test, swollen polar knob, smooth surface, very thin septa and spiral lamina, very high and narrow chamber cavity but markedly wider at the base, and slightly inwards convex lateral sides.

Description. Megalospheric form. External features. Test small to medium, thin, strongly bilaterally compressed, occasionally wavy, and with swollen polar knob; equatorial periphery regular and complanate to subcircular; axial periphery acute; surface rather smooth with a swollen polar knob; intercameral suture indistinct in the early whorl, becoming scarcely visible as being slightly raised, almost straight and radial in later whorls; sutures are visible if the specimen is submerged in water, and vary from 23 to 26 in the last whorl; spiral suture indistinct in early whorls, becoming distinct, thin, and flush to slightly depressed; the diameter of swollen polar knob varies from 0·075 to 0·20 mm. The diameter varies from 1·05 to 2·6 mm, thickness from 0·15 to 0·32 mm, and diameter/thickness ratio from 5·1/1 to 9·9/1.

Internal features. In axial section, protoconch circular from 0·025 to 0·05 mm in diameter; chamber cavity narrow and high, weakly attenuated towards the equatorial periphery and with almost parallel to inwards slightly convex lateral sides and markedly wide lower part with internally convex base; lateral wall rather thick in the polar region (0·10 to 0·15 mm), becoming thin in the last whorl (0·025 to 0·05 mm); surface polar knobs are merely thickenings of lateral walls. In equatorial section, the bilocular medium nucleoconch has a circular protoconch and subequal reniform deuteroconch; separating wall convex outwards; the protoconch from 0·025 to 0·075 mm in diameter; the deuteroconch from 0·025 × 0·05 to 0·0375 to 0·075 mm; the maximum width of nucleoconch from 0·075 to 0·10 mm; the spire of about three regular and rapidly opening whorls; the rate of spire opening from 1·85/1 to 2·5/1; spiral lamina very thin, regular, and increases in thickness distally; height of spiral cavity about seven to eighteen times thickness of spiral lamina; septa very thin, long, regularly spaced, maintaining their thickness throughout, and almost straight except distally which is strongly curved backwards to join spiral lamina; a few septa do not reach the spiral lamina and curve backwards to meet previous ones; about 8–9 septa occur in the first whorl, 16–19 in the second, and 22–29 in the third; chambers higher than long and almost crescentic in shape; chamber indices vary from 2/1 to 6/1.

Material. Microspheric form has not been found. Megalospheric forms are common at some horizons in Rock Unit IV.

Remarks. O. libyca thebensis subsp. nov. mainly differs from *O. libyca libyca* in having a rather smooth surface, a swollen polar knob, very thin spiral lamina and septa, a much thinner test, and in lacking surface granules and high ridges.

Distribution. In the Gebel Gurnah Section, *O. libyca thebensis* occurs in the upper Lower Eocene.

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